Amorphous State of Grape Functional Confection Dictates Differences in Bioactive Compound Release

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Background

Confections as a model for fruit bioactive delivery?

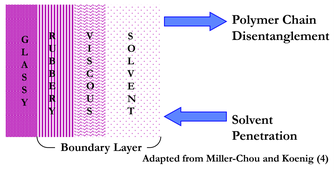
- Shelf stable, conveniently packaged
- Large range of amorphous forms can be achieved by manipulating interaction of starch and proteins (food polymers) with water and sugars (food plasticizers) in confections (1,2)

Different physical forms of solids (3)

Crystalline (rock candy, sugar crystals)

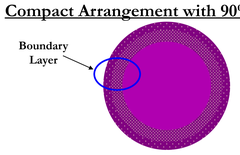
Amorphous

- Glassy: hard candy
- Rubbery: gummy bears
- Viscous: fruit preserve



Adapted from Miller-Chou and Koenig (4)

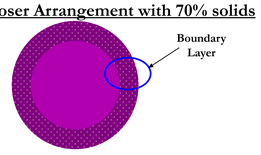
Compact Arrangement with 90% solids



Hard Candy

- Longer dwell time in mouth
- Small dose, controlled release
- Slower dissolution rate

Looser Arrangement with 70% solids



Gummy

- Faster disintegration
- Bolus dose, burst release
- Faster dissolution rate

Abstract

Fruit bioactives applied to the oral cavity has been shown to successfully treat oral maladies. Grape phytochemicals such as polyphenols, chalcones, and stilbenes have shown in previous studies to exhibit anti-neoplastic, anti-inflammatory, and anti-atherogenic properties. Localized release of bioactives in the mouth at a desired rate is the goal of controlled release formulations. Liquids spread too easily in the mouth and would dilute the active compounds therefore solids are more desirable. Food solids can exist as glassy, crystalline or rubbery physical states. Variation in moisture content and confection constituents, modulate between the glassy (hard candy model) and rubbery (gummy candy) forms. Therefore the state of the amorphous phases can dictate the rate of absorption of grape bioactives by buccal tissues. By differing soy protein and water inclusions, amorphous grape confections with a variety of physico-chemical and rheological characteristics were obtained. Glassy forms (5g) contained grape juice, high fructose, and sucrose while rubbery (6g) gummy contained grape juice, acid-thinned wheat starch and varying amounts of soy protein (0,25, and 50%). Increases in soy protein concentration attenuated starch gelation by weakening gel structure. Physical state dramatically influences dissolution rate thus limits the rate at which oral tissues can absorb these compounds. Dissolution studies revealed three release kinetics of bioactive ingredients in grape confections (hard candy versus soft gummy). Differences in the confection amorphous phase rheological properties related to differences in dissolution rate. Since the rate-limiting step to drug solubility/release is dissolution, its differences are expected to mitigate the mechanism of bioactive release within the amorphous food forms.

Conclusion

Distinct differences between the rates of bioactive release in the various confection forms implicate that differences in the confections' amorphous forms (glassy, rubbery, and viscous) can affect the rate of bioactive delivery in the oral cavity.

The heterogeneity among the slow (starch and 25% soy protein gummy), intermediate (waxy troche), and fast (hard candy and 50% soy protein) releasing confection can be developed to target delivery of food bioactives to specific sites in the body.

Literature Cited

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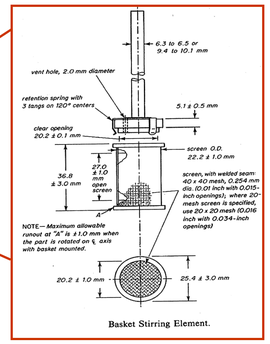
Acknowledgements

The authors gratefully acknowledge the following for their generous support:: The Center for Innovative Food Technology, College of Pharmacy, and members of Dr. Vodovotz and the Haas Chair Laboratory.

Methods and Materials

Dissolution Studies



Adapted from Abdou (6)

Release of bioactive compounds using dissolution apparatus

In vitro measure of solubility gradient of a solid (6,7).

Mandatory for all oral solid drugs but adapted here for solid food

Multiple factors affect dissolution rate (8)

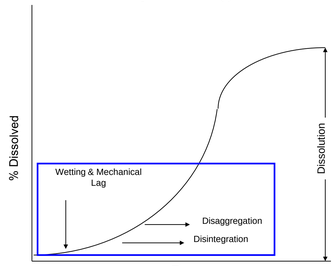
- Wetting
- Disintegration
- Disaggregation

Dissolution media

Potassium phosphate buffer at pH 6.5 (9)

8 chambers 200mL volume heated at 37°C

100 RPM rotation of basket



Results

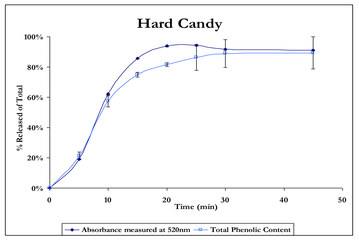


Figure 2. Hard Candy, glassy amorphous form (n=6). Dissolution rate (Δ Abs/Δ min.)= 2.02 x 10^{-2}

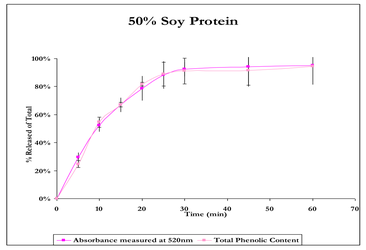


Figure 3. 50% Soy Protein, viscous amorphous form (n=6). Dissolution rate (Δ Abs/Δ min.)= 1.58 x 10^{-2}

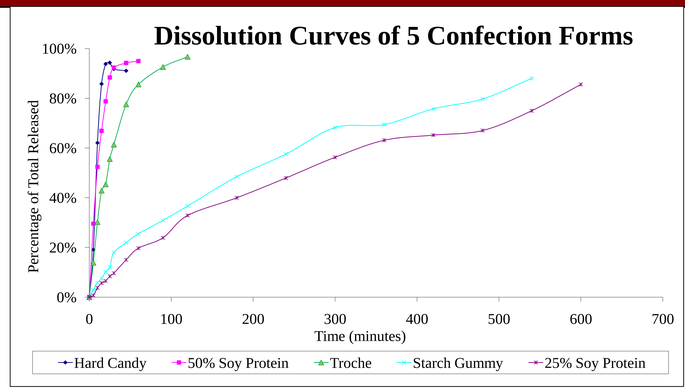


Figure 1. Dissolution Curves of 5 Confections. Troche composed of Lyophilized Black Raspberries and All remaining with Grape Juice. Percentage of Total Released was measured at λ_{max} of 520 nm

Table 1. Total Phenolic Content of Ingredients and Confections using Folin-Ciocalteu Reagent (n=6)

Raw Materials	Average GAE[a] (mg/g)	STD[b] Deviation
Lyophilized Black Raspberry	46.91	0.26
Lyophilized Grape Juice	25.32	0.23
Soy Protein Isolate	5.46	0.44
Confections (processed)[c]		
Hard Candy	2.07	0.20
Troche	27.55	0.69
Starch Gummy	4.97	0.37
25% Soy Protein Gummy[d]	4.88	0.52
50% Soy Protein Gummy[d]	5.40	0.84

a Gallic acid equivalents mg per gram of dried sample *b* Standard deviation
c Reported values from confection samples not calculated from amount of raw sample added
d Percentage of soy protein and starch was varied while percentage of grape juice was held constant from the total.

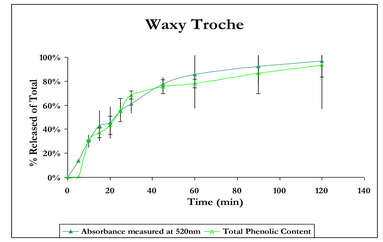


Figure 4. Waxy Troche, glassy amorphous form (n=6). Dissolution rate (Δ Abs/Δ min.)= 8.06 x 10^{-3}

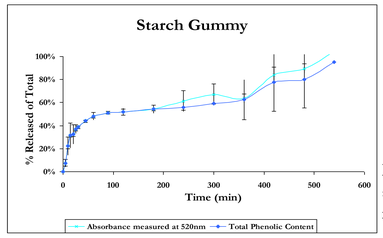


Figure 5. Starch Gummy, rubbery amorphous form (n=6). Dissolution rate (Δ Abs/Δ min.)= 1.63 x 10^{-3}

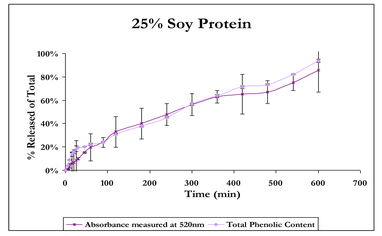


Figure 6. 25% Soy Protein, rubbery amorphous form (n=6). Dissolution rate (Δ Abs/Δ min.)= 1.48 x 10^{-3}